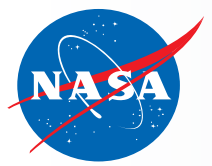


Liner Physics Team Overview

Douglas M. Nark (for Liner Team)
NASA Langley Research Center, Hampton, VA

Acoustics Technical Working Group Meeting
Hampton, VA
March 21-22, 2023



NASA LaRC Liner Physics Team

Aeroacoustics Branch:

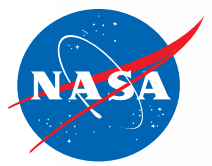
Martha Brown, Alex Carr, Max Reid

Structural Acoustics Branch:

**Matt Galles, Brian Howerton, Mike Jones, Jordan Kreitzman,
Doug Nark, Chelsea Solano**

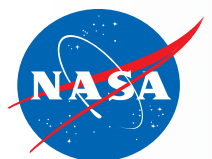
On-site contractor support:

Larry Becker



Outline

- **Background**
- **Liner Modeling: Perforate Model Database**
- **Application: Treated Bifurcation**
- **Acoustic Liner Workshop**
- **External Collaborations**
- **References**



Background: NASA LaRC Liner Technology Facility

High Intensity Modal Impedance Tube (HIMIT)

- Mach 0.0, SPL \leq 170 dB, Freq \leq **6 kHz**
- Tone and Broadband sources

Normal Incidence Tube (NIT)

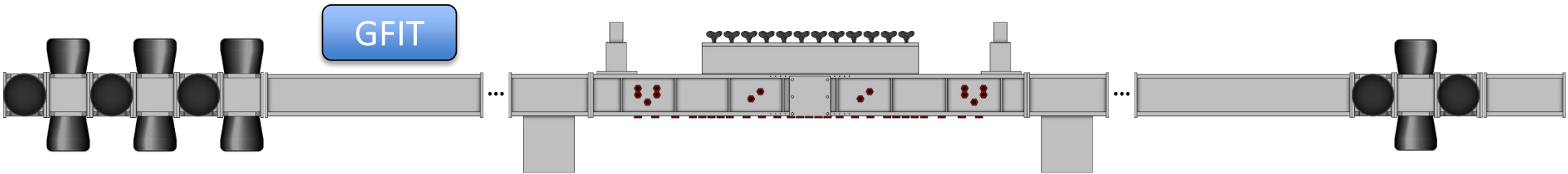
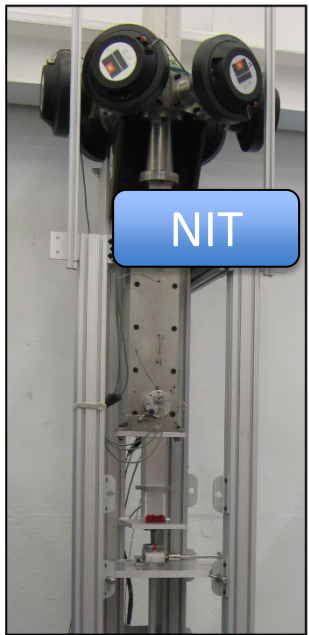
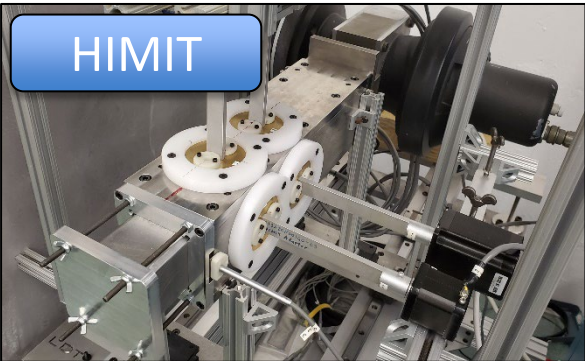
- Mach 0.0, SPL \leq 155 dB, Freq \leq 3 kHz
- Tone and Broadband sources

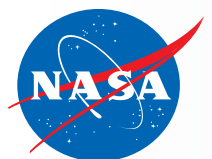
Grazing Flow Impedance Tube (GFIT)

- Mach \leq 0.6, SPL \leq 155 dB, Freq \leq 3 kHz
- Tone source

Curved Duct Test Rig (CDTR)

- Mach \leq 0.5, SPL \leq 135 dB, Freq \leq 3 kHz
- *Controlled* Tonal mode and Broadband sources

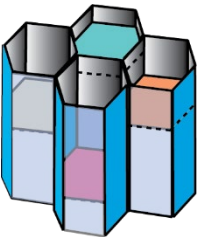




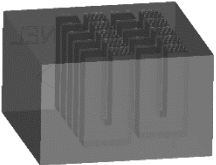
Background: Liner Concept Modeling and Design

Liner Modeling

MDOF



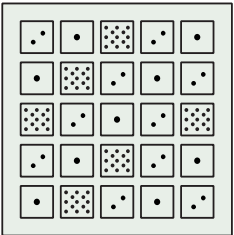
Slotted core



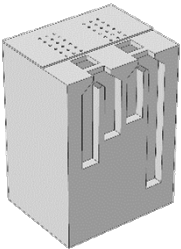
Variable Depth



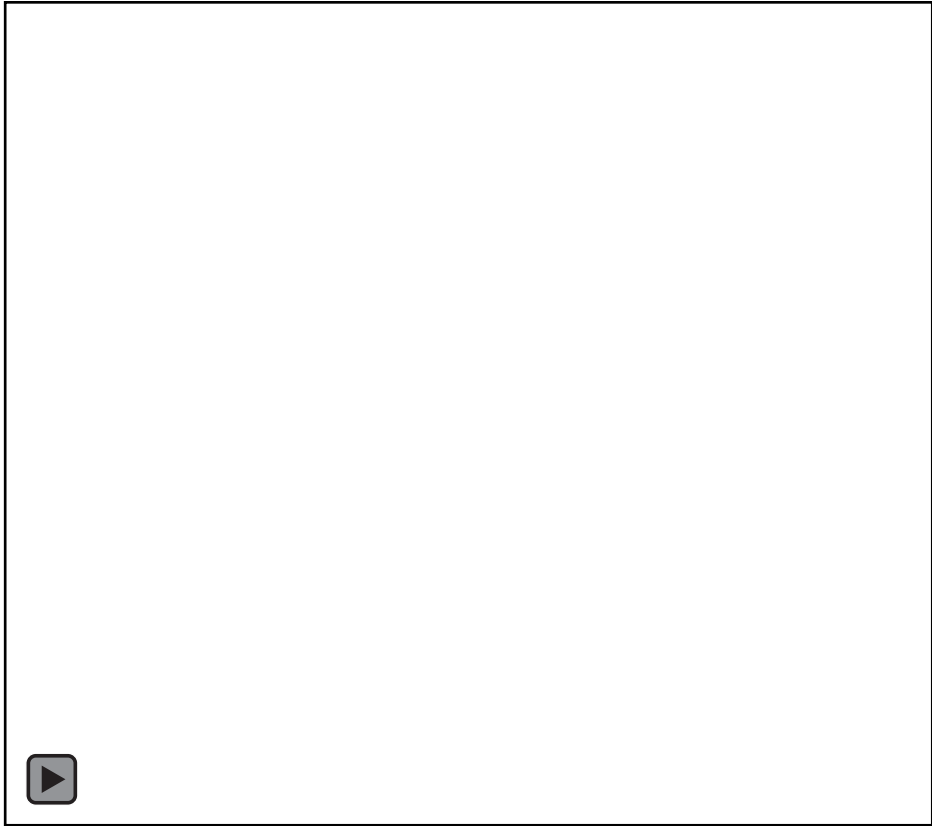
Distributed facesheet



Shared port inlet



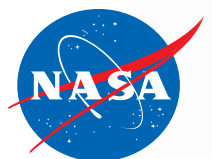
Application



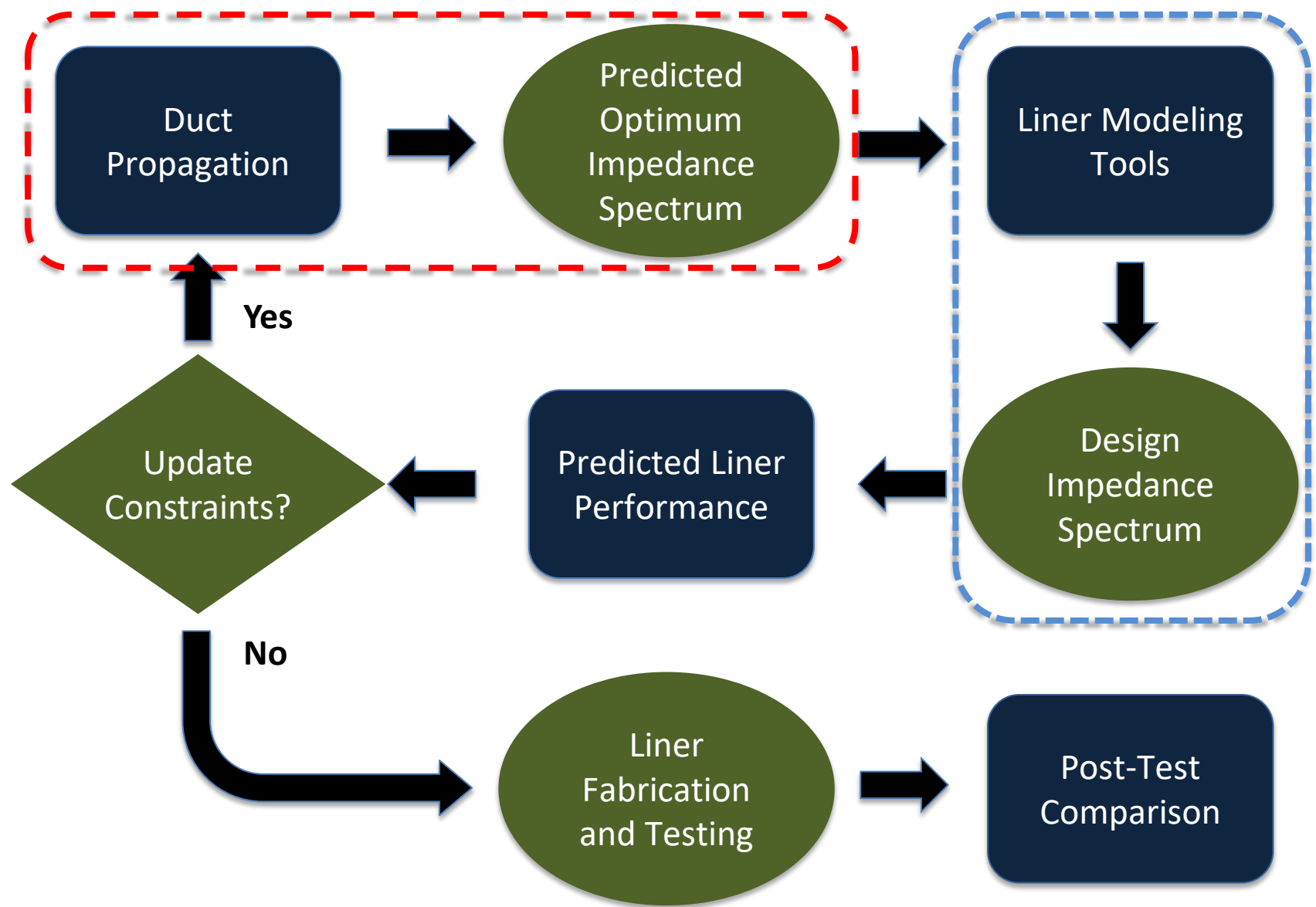
Flight Test



Develop liner (acoustic/multifunctional) modeling/design tools and advanced liner concepts to achieve increased noise reduction over a wider frequency range and to reduce liner drag



Background: Acoustic Liner Design (Indirect Approach)

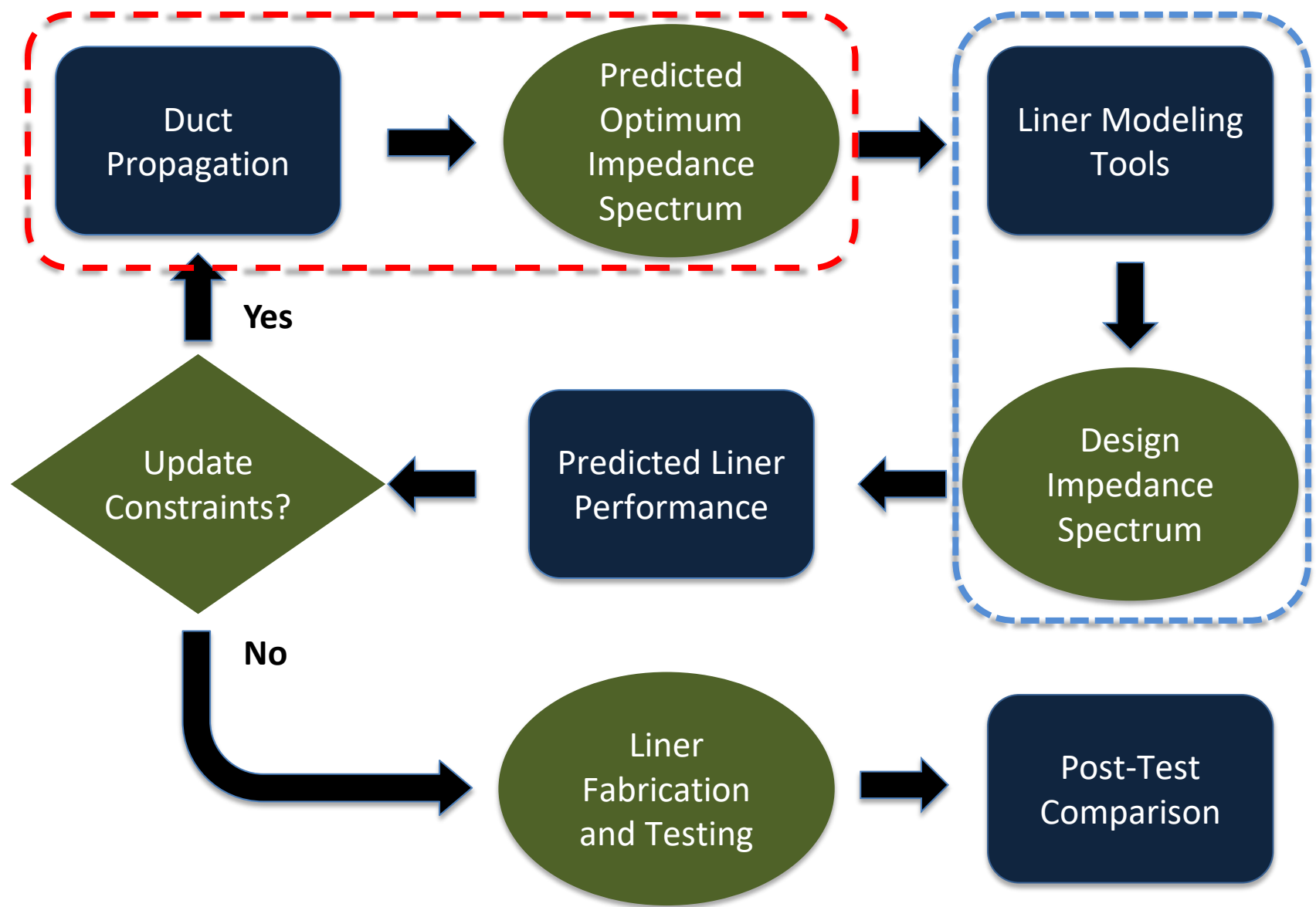


Updates:

- Statistical Source
- Optimizer implementation
- Improved liner models



Background: Acoustic Liner Design (Indirect Approach)

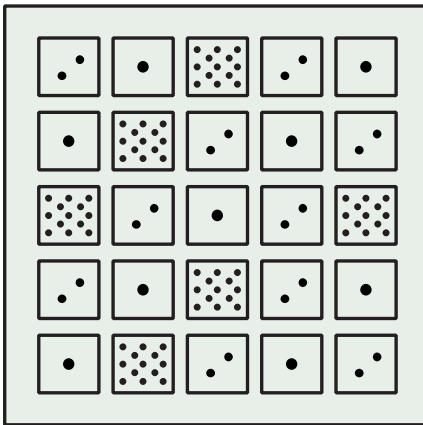


Updates:

- Statistical Source
- Optimizer implementation
- Improved liner models

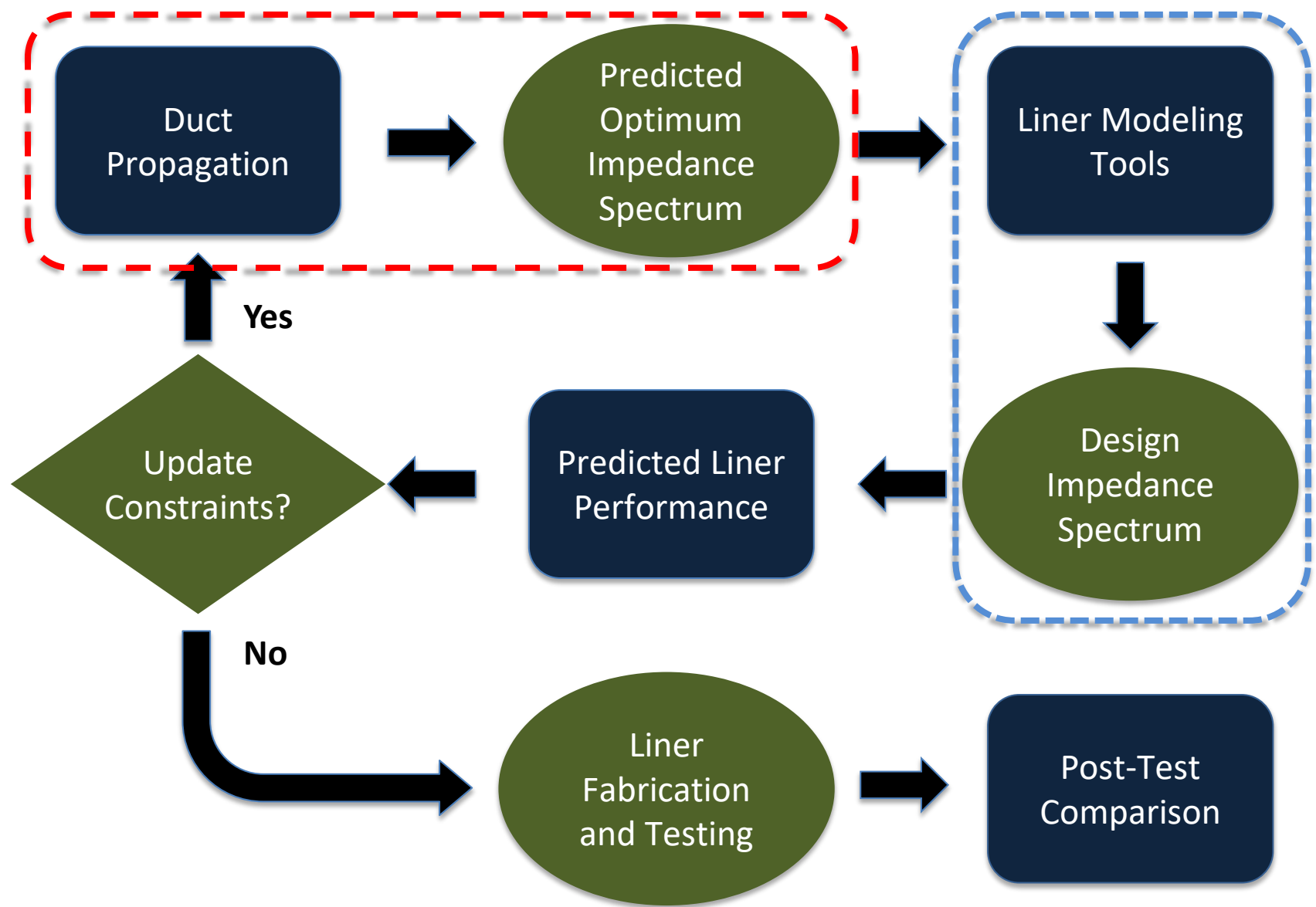
Recent applications:

Brown:
Distributed Facesheet





Background: Acoustic Liner Design (Indirect Approach)



Updates:

- Statistical Source
- Optimizer implementation
- Improved liner models

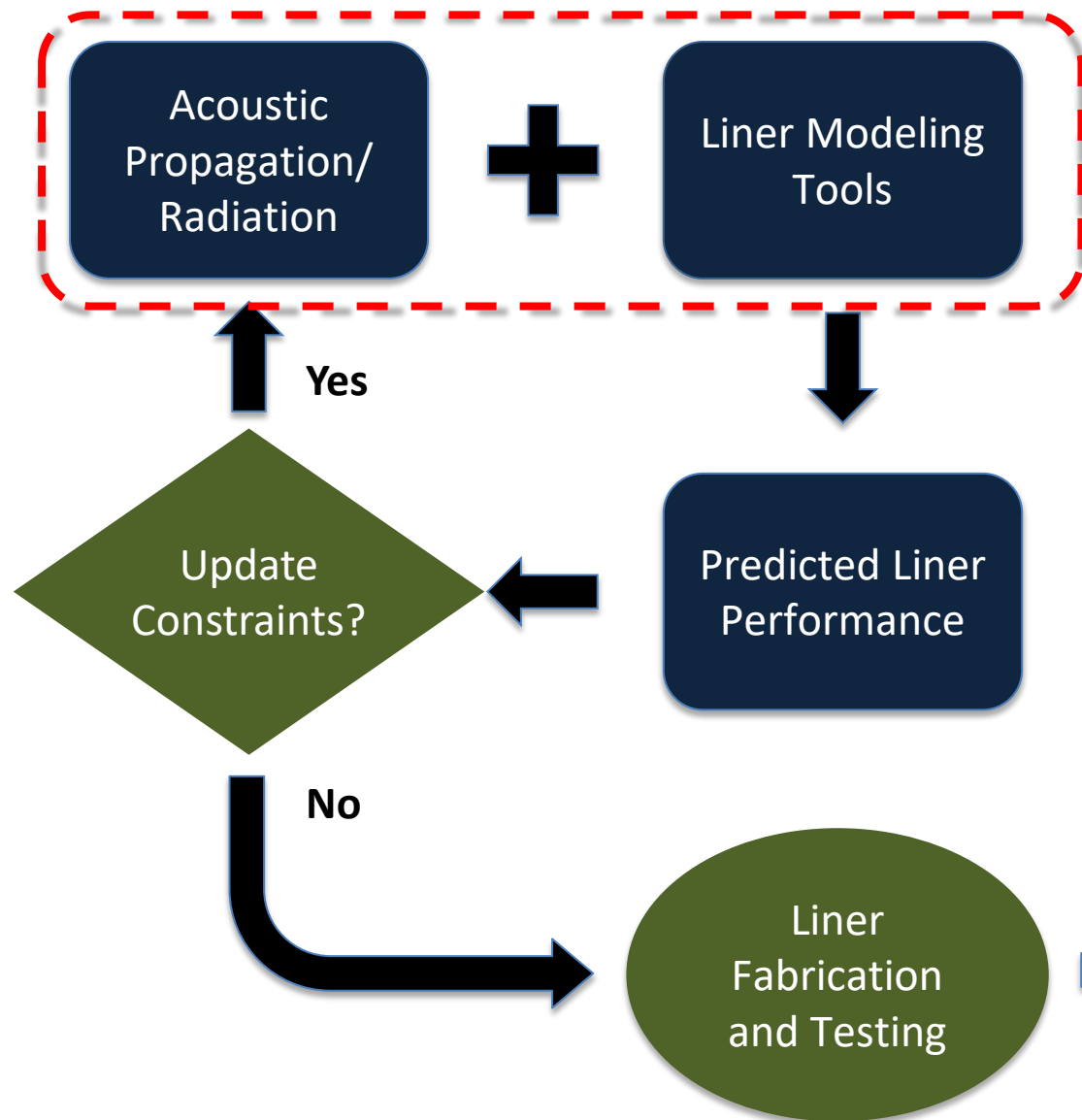
Current Applications:

Galles, Kreitzman:
Variable Depth





Background: Acoustic Liner Design (Direct Approach)



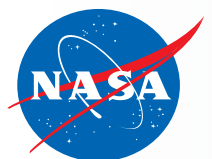
Direct Approach

- Optimize liner parameters to achieve maximum attenuation over range of frequencies and flow conditions
- Build impedance is obtained as part of the optimization process (target impedance is not considered)
- Liner concept chosen at the beginning of process

Current Applications:

Galles, Kreitzman:
Variable Depth





Liner Concept Modeling

| Model | Authors | Reference |
|-------|--|---------------------------|
| 1 | Motsinger, Kraft | NASA RP-1258, August 1991 |
| 2 | Parrott 'correction' to Model 3 | - |
| 3 | Yu, Ruiz, Kwan | AIAA 2008-2930, May 2008 |
| 4 | Crandall (per Betts) | Betts PhD, 2000 |
| 5 | Jones, Howerton, Ayle | AIAA 2012-2194, June 2012 |
| 6 | Guess | JSV (40), 1975 |
| 7 | Kirby and Cummings | JSV (217), 1998 |
| 8 | Maa (with grazing flow effect added) | JASA (104) 1998 |
| 9 | Elnady, Boden | AIAA 2003-3304, May 2003 |
| 10 | Parrott, Jones – 2006 | AIAA 2006-2402, May 2006 |
| 11 | Parrott – 2008 | TWG, September 2008 |
| 12 | Schultz, Liu, Cattafesta, Sheplak, Jones | AIAA 2009-3301, May 2009 |
| 13 | Kabral, Boden, Elnady | AIAA 2003-3304, June 2014 |

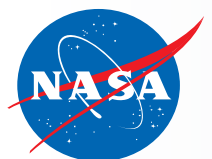
Perforate Impedance Model

Other methods were not included

- limited application
- difficult measurement requirements
- inefficient computations
- insufficient time

Many are based on models developed by Crandall or Guess

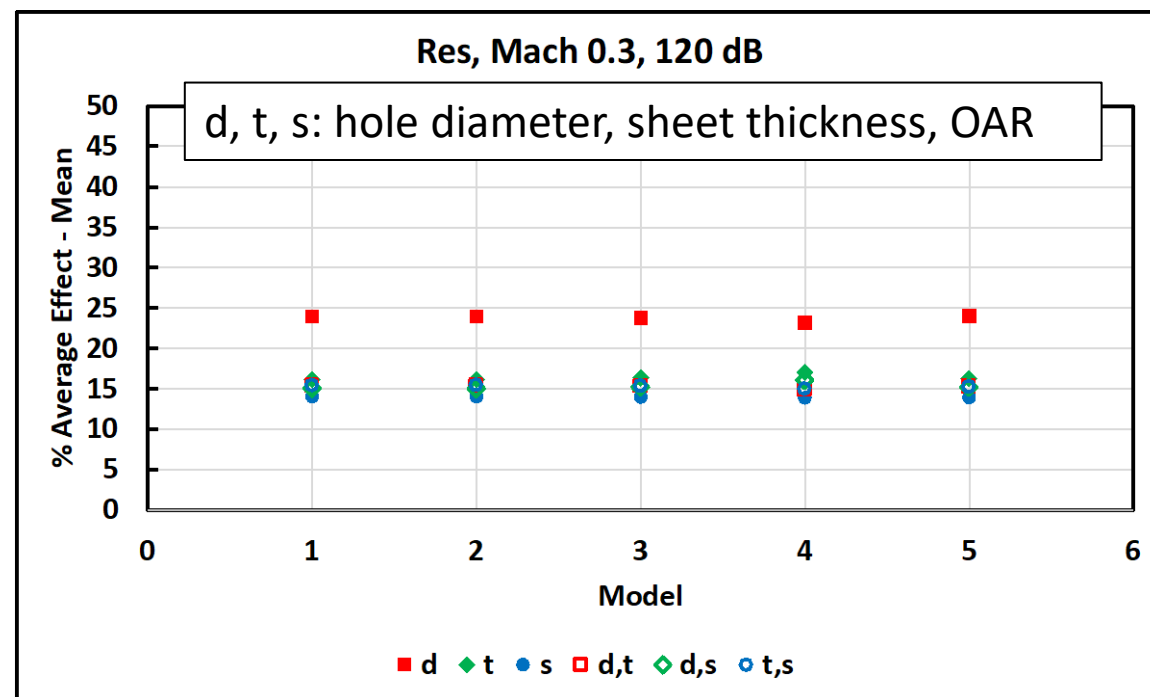
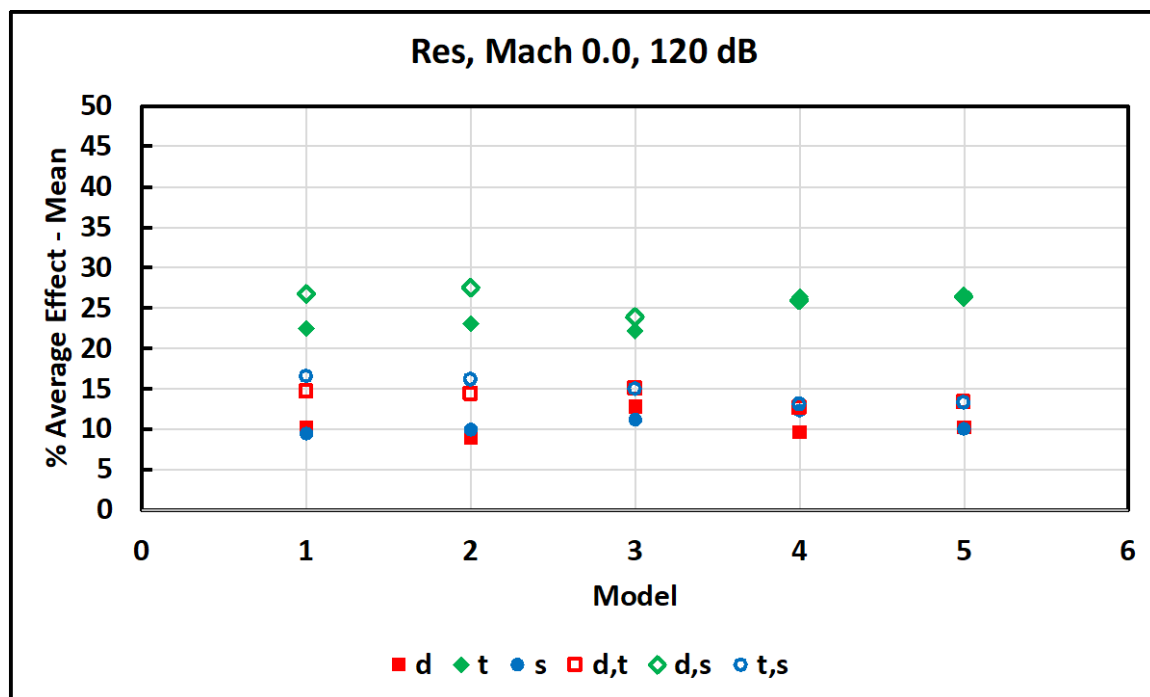
5 years (and counting) study



Liner Concept Modeling

Analysis: 2-Factorial

- Each model demonstrates similar trends regarding effects of the different parameters
- Averaged results presented below



- Note the importance of geometry pairing effects; will consider this as part of model refinement
- With flow, hole diameter becomes increasingly important.
- If h or M are included in the 2-factorial analysis, M dominates resistance and h dominates reactance



Liner Concept Modeling

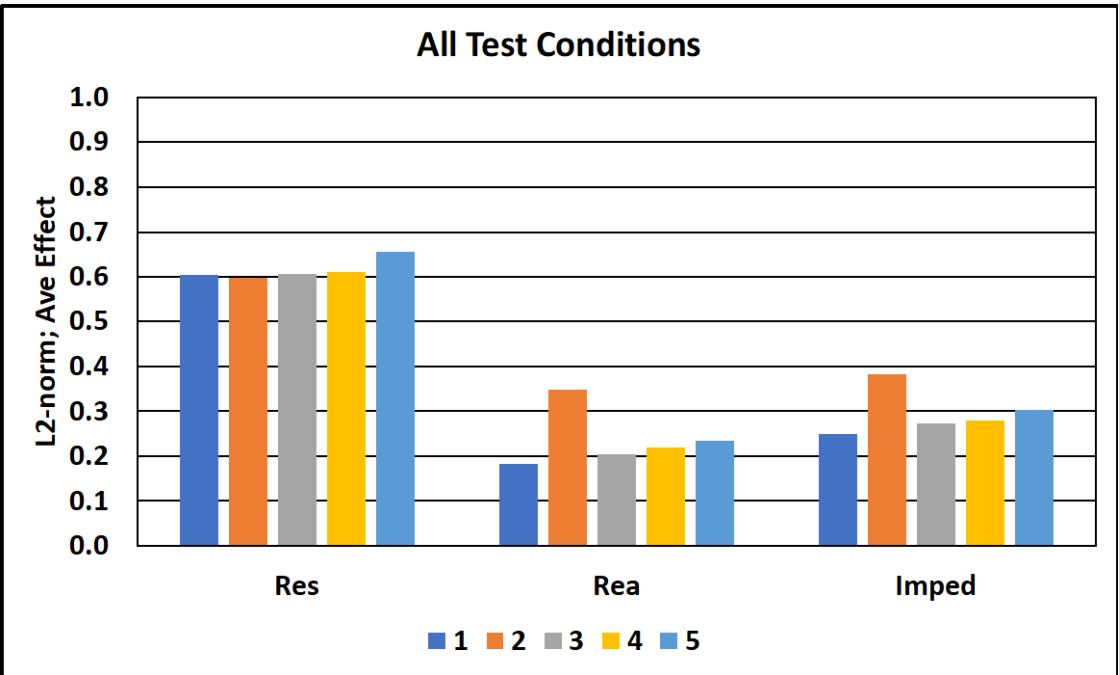
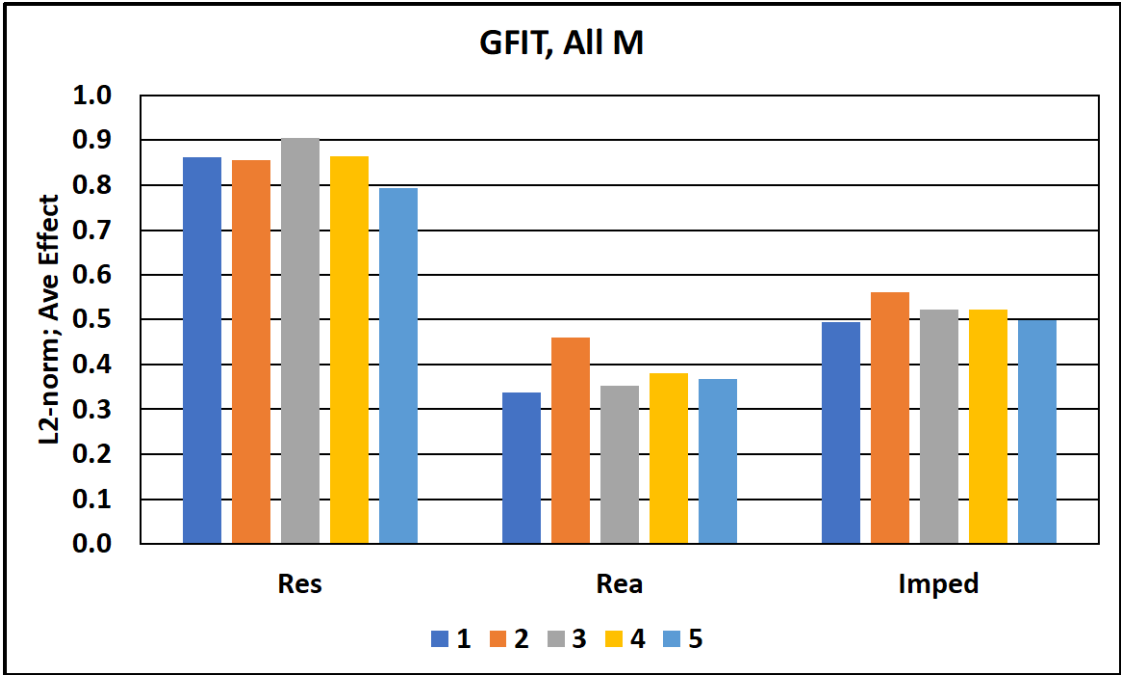
These models compared most favorably with NASA LaRC NIT and GFIT data
249 test cases acquired with swept sine source.

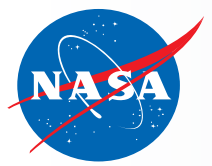
- NIT (73 samples) or GFIT (9 samples)
- Mach 0.0, 0.3, or 0.5
- Source SPLs of 100, 120, or 140 dB

Note: “Best model” is different for resistance, reactance, and impedance evaluations. It also varies with data type. For the next step, we will apply optimization correction factors to Model 1.

L2 norm

$$\frac{\left[\sum_{i=1}^{\# \text{ cases}} (\zeta_m - \zeta_p)_i (\zeta_m - \zeta_p)_i^* \right]^{0.5}}{\left[\sum_{i=1}^{\# \text{ cases}} (\zeta_m)_i (\zeta_m)_i^* \right]^{0.5}}$$





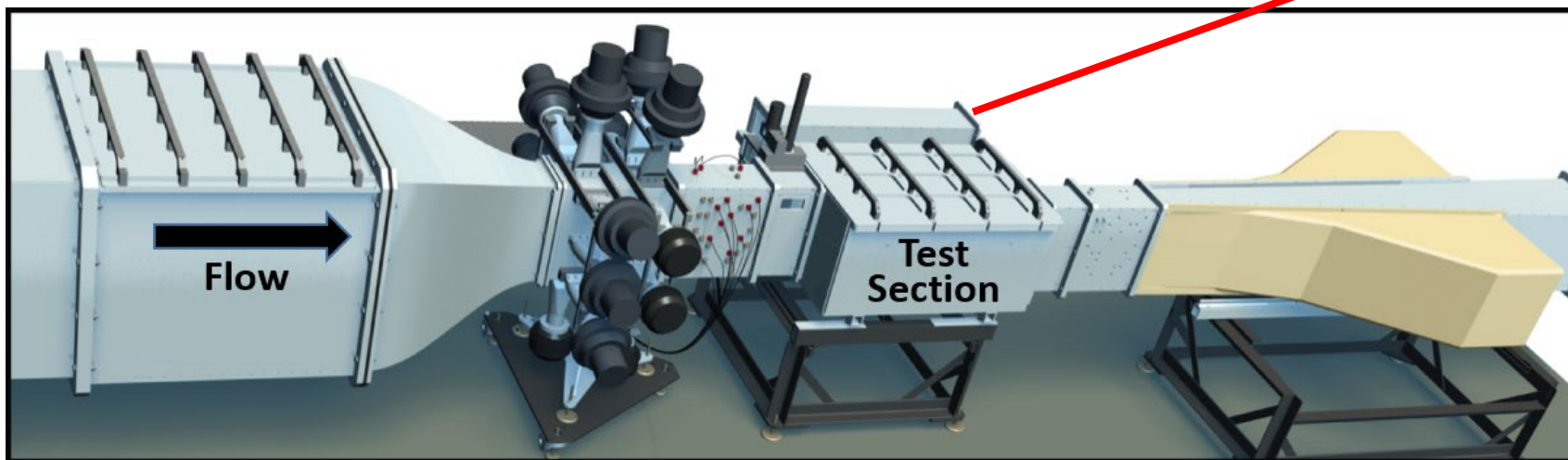
Liner Concept Modeling (Next Steps)

- Use SciPy optimizers to determine correction factors for selected model
 - Will be presented at AIAA Aeroacoustics 2023
- All NIT and GFIT data will be made available to the public; targeting mid-2023
- Investigate effects of other liner features
 - Variable impedance (e.g., variable porosity, variable depth)
 - Partition thickness
- Insert your suggestions here!

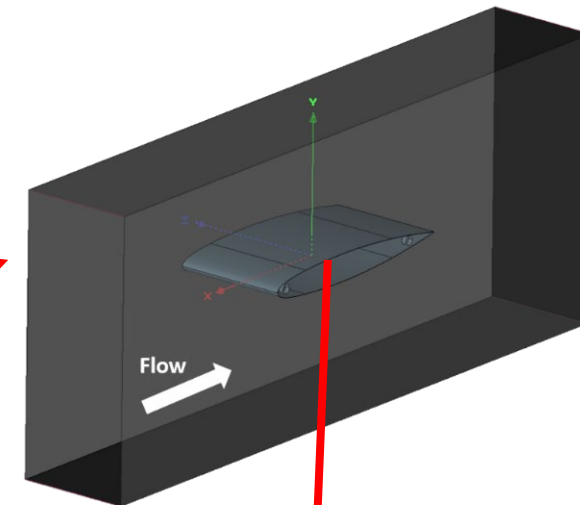
Acoustically Treated Bifurcations

CDTR Test

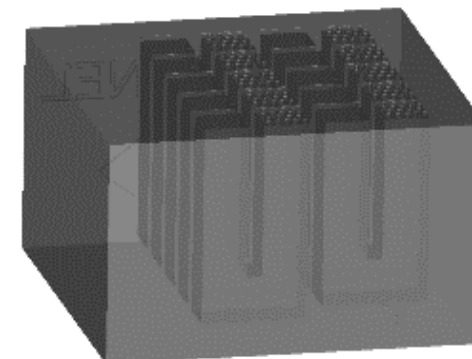
- Significant interest in the development and optimal placement of advanced broadband acoustic liner concepts
- Acoustic treatment on the engine bifurcations (i.e., engine pylon and lower bifurcation) may be an excellent candidate for increased attention



Bifurcation in CDTR Test Section

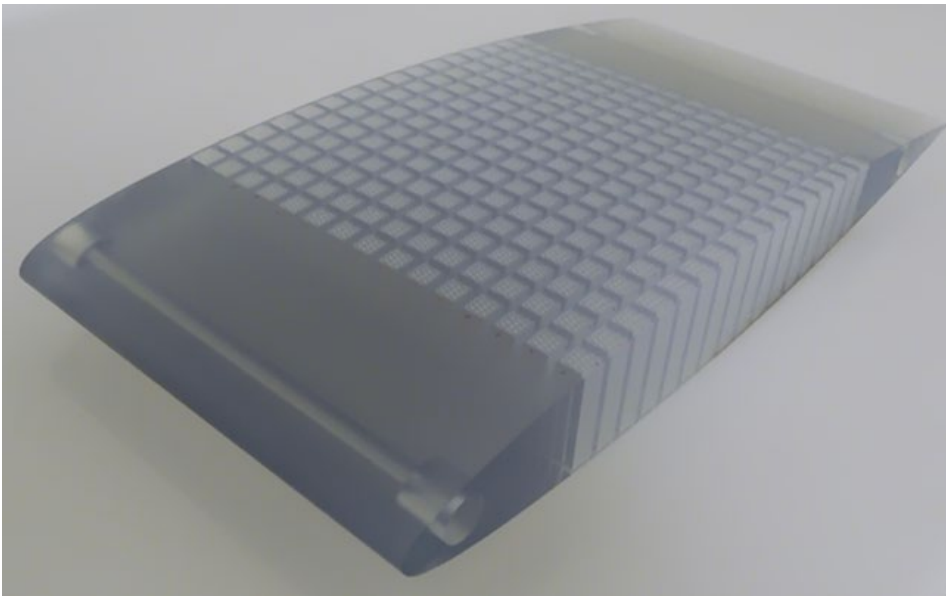


Slotted core



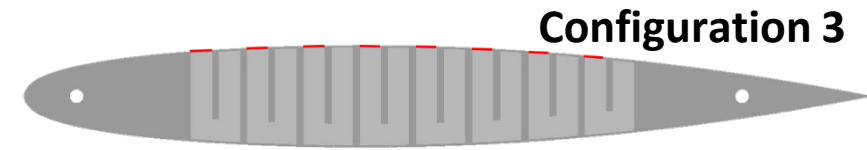
Acoustically Treated Bifurcations

CDTR test samples Profile: NACA0012-64

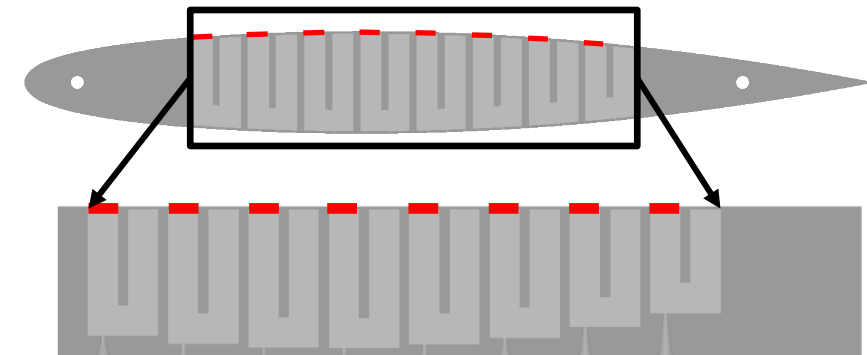


0.4" x 0.4" cells

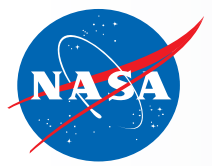
- 15 Spanwise
- 16 Chordwise



- GFIT sample fabricated to validate impedance modeling for slotted core

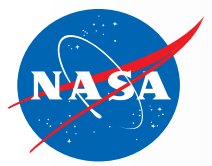


- Additional design to maximize attenuation in the CDTR over a broadband frequency range



Acoustically Treated Bifurcations

- **Purpose:**
 - Collect acoustic pressure data for acoustically treated bifurcations with/without treated sidewalls
 - Further validate treatment design tools and liner models
 - Gain confidence in bifurcation treatment design and effectiveness
- **Specific Data Collected**
 - Acoustic pressure data with upstream (aft mode) source at Mach 0.0, 0.25, 0.45
 - Controlled-Mode (h,v): [(0,0), (0,1), (0,2), (1,0), (1,1), (0,3) modes]; 0.4 – 3.0 kHz, 0.2 kHz increments; 130 dB
 - Multi-Mode (Uncontrolled-Mode); 0.4 – 3.0 kHz, 0.2 kHz increments; max SPL
 - Broadband; 0.2—5.0 kHz, max SPL
- **Data Analyses and Reports:**
 - Results to be reported in 2023 AIAA AVIATION Forum conference paper



Acoustic Liner Workshop

Monday, March 20, 2023

- **Attendees: 55**

Presentations:

- **Design/Modeling/Optimization (tools/models for both conventional and novel liner concepts)**
 - Brown (NASA LaRC), Hu (ODU), Kreitzman (NASA LaRC), Reimann (Raytheon), Sharma (WSU)
- **Evaluation (test rigs, impedance eduction)**
 - Carr (NASA LaRC), Drouin (Spirit AeroSystems), Howerton (NASA LaRC), June (NASA LaRC), Sutliff (NASA GRC)
- **Implementation/Manufacturing (manufacturability, durability, sizing, placement, weight, drag, cost)**
 - Chien (Collins), Nesbitt (Boeing Ret.), Schuster (Honeywell), Smith (Hexcel)



External Collaborations

Space Act Agreements (SAA): in progress

Hexcel – Evaluation of NASA-designed novel liner concepts

Honeywell – Acoustic liner tests

OSU – Thermoacoustic liner evaluation

Raytheon – Analysis and testing of novel liner concepts

WSU – Analysis and testing of TPMS liner concepts

SAA: planned

Collins, Honeywell

Other collaborations

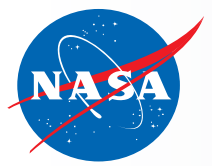
IFAR (International agreement) – Evaluate effects of flow direction or multitone source on impedance

ODU (NIA) – Time domain method to study acoustic scattering with liners

WSU (EPSCoR grant) – Development of variable-density foam for improved noise reduction

AARC – Comparison of predicted (Avallone) and measured (NASA LaRC and UFSC) impedances

Regular interactions with NASA GRC acoustics branch



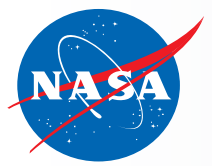
References

Published

- Howerton, Jones, "Low-Drag Acoustic Liner Development," NASA TM-20220014642, Sept 2022
- Jones, Carr, Nark, Becker, "Implementation of the NASA High Intensity Modal Impedance Tube," NASA TM-20220017773, Dec 2022
- Johnston, Brown, Jones, Sharma, "Comparing Acoustic Prediction Methods for Additively Manufactured Porous Structures," NOVEM 2023, Jan 2023
- Solano, Jones, Carr, Nark, "High Intensity Modal Impedance Tube Development at NASA Langley," NASA TM-20230000292, Feb 2023

Abstracts accepted for 29th AIAA/CEAS Aeroacoustics Conference

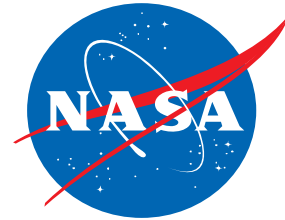
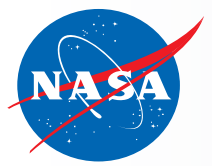
- Howerton, Jones, "Acoustic Liner Drag: Measurement Uncertainty Reduction and Application to Novel Perforate Geometries"
- Solano, Howerton, Jones, "A Multilayered Facesheet Acoustic Liner with Gaps Between Layers"
- Nark, Jones, "A Fundamental Study of Bifurcation Acoustic Treatment Effects on Aft-Fan Engine Noise"
- Bonomo, Quinitino, Cordioli, Avallone, Jones, Howerton, Nark, "A Comparison of Impedance Eduction Test Rigs with Different Flow Profiles"
- Brown, Solano, Jones, "Assessment of Nonlocally Reacting Effects of Large Diameters on the Acoustic Impedance of Perforate-Over-Honeycomb Liners"
- Brown, Galles, Nark, Jones, "Preliminary Design of a Distributed Facesheet Acoustic Liner for Broadband Acoustic Attenuation"
- Galles, Jones, Nark, "Design Optimization of Variable Depth Liners with Grazing Flow for Ducted Proprotor Applications"
- Jones, Nark, "Comparisons of Impedance Prediction Models for Perforate-over-Honeycomb Liners"
- Hu, Nark, "On a stabilization of the Ingard-Myers impedance boundary condition"

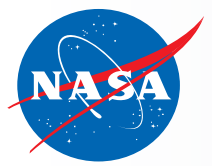


Acknowledgements

Special thanks to the Advanced Air Transport Technology and Revolutionary Vertical Lift Technology Projects of the NASA Advanced Air Vehicles Program for funding this work







Backup Slides

